Nine Regimes of Radio Spectrum Management: A 4-Step Decision Guide

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Summary

Diverse radio spectrum management regimes are defined according to 4 levels of questions:

- Should frequencies be allocated according to a harmonised plan?
- Should the technologies allowed be standardised?
- Should spectrum usage rights be exclusive, eased, or collective?
- Should usage rights be assigned through market mechanisms, administrative procedures, or hybrid procedures?

This paper establishes a balanced set of decision criteria for each question. It describes nine regimes resulting from the combined answers. The taxonomy illustrates the possible rationales for a diversity of regimes broader than the usually exposed standard trilogy of Command and Control, Market and Commons: This includes Harmonised flexibility, Administered flexibility, Technology flexibility in Command and Control context, Harmonised flexibility Plus, Private Commons and California Dream. The nine regimes can also be considered as a map with which to navigate in order to accommodate institutional and technological transitions. This allows decision-makers to come-up with informed choices using all the technical information available, and based on definite criteria and a rigorous methodology.

Wireless services will undergo a major expansion in the next decade. The generally accepted view is that this will provoke an increased need for radio spectrum. Major technological changes are under way as well, which might help in improving its efficient use, but also warrant savvier management methods.[1]

The debate on adequate, future-oriented, spectrum management is currently reaching a critical point. A trend towards flexibility in the form of market mechanisms (auctions of spectrum property rights and trading) was initiated in New Zealand, then the U.S. in 1993, and expanded in a number of European and Asian countries as of 2000. It was consistently formalised in 2002 by the FCC Spectrum Task Force Report in the U.S.[2] and the Martin Cave Report in the UK[3]. The two reports[4] translated into a comprehensive, market-oriented spectrum management framework that has served as an underlying reference to subsequent policy initiatives in Europe since this time.

It seems, however, that this trend is encountering delays where it is already implemented or favourably considered, and facing fierce opposition in territories it has not conquered. It might consequently be useful to sort out the alternatives, list the arguments exchanged, look into the prospects offered by ongoing technological developments in wireless, and pave the way for possible transitions paths.

This paper proposes to:

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[1] This paper has strongly benefited from the research being carried out within the European Commission Specific Support Action SPORT VIEWS (Spectrum Policies and Radio Technologies for Viable Wireless Services, Contract No 027297). Comments and contributions have been received from Frédéric Pujol, Marvin Sirbu and anonymous referees. However, the author carries sole responsibility for the views expressed in this article. They do not in particular necessarily reflect those of the European Commission or the SPORT VIEWS consortium partners.

[2] Federal Communications Commission Spectrum Policy Task Force Report, November 2002
http://www.fcc.gov/sptf/

[3] *Review of Radio Spectrum Management, An Independent review for the Department of Trade and Industry and HM Treasury*, By Professor Martin Cave, March 2002
http://www.spectrumreview.radio.gov.uk/

[4] For an overview of spectrum management methods and the international experience: J. Scott Marcus, L. Nett, M. Scanlan, U. Stumpf, M. Cave, G. Pogorel, *Towards more flexible spectrum regulation*, WIK-BundesNetzAgentur, December 2005.

- Explore the whole range of choices available to regulators and industry in establishing a radio spectrum management policy by expanding beyond the standard trilogy of Command and Control, Market and Commons.
- Organise and clarify the expanded set of alternatives to be considered.
- List the criteria whereby the necessary choices and decisions can be made.

1. Definitions: Four dimensions of spectrum management

A spectrum management regime comprises four dimensions that have to be successively analysed.[5] The concepts and alternative approaches must be explored at the following levels:

- Allocation: service harmonisation or service flexibility
- Technology: standardisation or technology flexibility
- Usage rights definition: alternative regimes
- Assignment modes of spectrum usage rights

We will successively examine the above issues and alternatives.

1.1. Allocation of frequencies: Service harmonisation or service flexibility?

Harmonisation is intended as allocating a frequency band or set of frequency bands for a service application or category of services. It consists in defining measures at international (ITU), regional (Europe, America, Asia), and national levels and poses limitations on service flexibility.

Harmonisation does not have to be implemented all over the spectrum. There can be harmonised bands where justified, and non-harmonised bands elsewhere in the spectrum. This translates into an opposition between no harmonisation all across the spectrum (or commercial spectrum) and harmonisation for distinct wireless services sets ("clusters").

[5] Johannes M. Bauer, *A Comparative Analysis of Spectrum Management Regimes*, Quello Working Papers, 2002

1.2. Technology: Standardisation or technology flexibility

Standardisation is intended as designating a technology or set of technologies to provide a category of service. It aims to ensure that the equipment used meets the technical requirements specified in technical *product standards,* or specifications, in order to provide market advantage in terms of better coexistence or interoperability, cross-border roaming, economies of scale, etc. Standards can be determined by public bodies such as ETSI, or the market (industry-led), and then mandated by regulation or not. It is assumed that standardisation can only reasonably occur in a harmonised context.

For reasons of clarity, it is important to draw this distinction between harmonisation and standardisation. Harmonisation of frequency bands, is an option at frequency allocation level, standardisation takes place at technology level. There can be harmonisation with, or without, standardisation. There are obvious relationships between the two, as technical standards have to cope with the physical qualities of frequencies. Yet harmonisation and standardisation do not necessarily go hand in hand. Various technical standards, or even non-standardised technologies, can possibly be used in harmonised bands. Although this distinction is needed, the confusion can be found in some studies on spectrum policy[6].

1.3. Usage rights definition

In the spectrum context, the following categories of usage rights can be defined:

Property rights have been widely heralded as a major factor of economic and social dynamic evolution. There can be:

- Exclusive property rights (without easements)
- Property rights with easements: they make provisions for sharing, overlay, underlay, and Dynamic Frequency Selection (DFS). DFS can be intended in a restrictive sense as the possibility of shifting between a set of predetermined harmonised bands, or, more extensively, as the possibility of shifting across large areas of the spectrum. It is compatible with all non-exclusive property based regimes. The SPORT VIEWS project has examined the potential interest of introducing reasoned easements. This perspective of

[6] Booz-Allen, *Study for the UMTS Forum*, 2006

disaggregating property rights to benefit from technology evolution has been extensively explored by Martin Cave[7].

Collective use, the third type of usage rights, became popular as "commons" in the late nineties with the advent of WiFi and was promoted as a far-reaching, future-oriented model. The possible extent of collective use, and conversely, of property rights, was extensively explored in a recent EU Study.[8]

1.4. Assignment modes of spectrum usage rights

There are two main categories of usage right assignment modes:

- Comparative administrative procedures, which include:
  - Pure administrative procedures.
  - Hybrid modes, such as administrative procedures with a bidding price as part of a weighted multi-criterion formula. They put together the contribution to local and regional broadband development and a financial element.[9] There is a price component, but the licence remains under administrative control.
  - Administered incentive pricing, which also remains within the category of administrative control.

- Auctions resulting in exclusive property rights, which represent the quintessential market solution for the assignment of spectrum usage rights. Trading is a complement to this approach for secondary markets.

Assignment modes have been the subject of numerous studies.[10]

The table below summarises the overall alternatives arranged in a 4-step decision tree designing nine spectrum management regimes:

[7] Cave M., New spectrum-using technologies and the future of spectrum management: a European policy perspective, OFCOM May 2006.

[8] Legal, economic and technical aspects of collective use of spectrum in the European Community, Final Report by Mott MacDonald Ltd, Aegis Systems Limited, IDATE, Indepen Ltd and Wik Consult

[9] ARCEP (France) 3,5 GHz WLL Wimax Assignnment, July 2006

[10] See above FCC and Martin Cave, both 2002

1.5. Nine spectrum management regimes: a 4-step decision guide

Frequency Allocation: Harmonisation Or Not **STEP 1**	**Technologies** **Standardisation or not** **STEP 2**	**Usage rights** **STEP 3**	**Spectrum assignment mode** **STEP 4**	**Spectrum Management Regime #**
Harmonised spectrum (no Service flexibility)	Standardisation (no techno flexibility)	Property rights/- Exclusive	a/Administrative Assignment Procedure/Hybrid b/ Auctions/Trading	**1a Standard Command and Control (CC)** **1b Technology Control/Property rights (PR) Market**
		Property rights/with Easements	a/Administrative Assignment Procedure/Hybrid b/ Auctions/Trading	**2a Mitigated CC with easements** **2b Technical CC+ Mitigated Market**
		Collective use		**3 CC Collective**
Harmonised spectrum (no Service flexibility)	Techno flexibility NO Standardisation	Property rights Exclusive	a/Administrative Assignment Procedure/Hybrid b/ Auctions/Trading	**4a Technology flexibility in CC context** **4b Harmonised flexibility**
		Property rights with. Easements	a/ Administrative Assignment Procedure/Hybrid b/ Auctions/Trading	**5a Controlled flexibility** **5b Harmonised flexibility Plus**
		Collective Use		**6 Standard 'Commons" Regime**
Service flexibility) NO Harmonisation	Techno flexibility NO Standardisation	Property rights Exclusive	a/Administrative Assignment Procedure/Hybrid b/ Auctions/Trading	**7a Administered Flexibility** **7b Pure market regime: libertarian**
		Property rights with. Easements	a/Administrative Assignment Procedure/Hybrid b/ Auctions/Trading	**8a Technology Flexibility/Administered semi-PR Market** **8b Mitigated Market regime: semi-libertarian**
		Collective Use		**9 California Dream**

The standard trilogy is present in this table. We recognise regime 1a as the traditional Command and Control model. Regime 7b qualifies as a full property-based market regime: one single market process combining flexible frequency allocation and technical choice. Regime 6 is the "commons" model.

What this table illustrates, however, is a diversity of regimes broader that usually exposed. Before looking into the grounds on which each of these regimes could be pragmatically justified, let us provide some brief descriptions. Regime 1b, for instance, combines a hybrid of command and control at a frequency allocation and technology level, and auctions for property rights assignment. Harmonisation (at allocation level) is thus compatible with some degree of market mechanisms, at assignment level, as seen in the UMTS case in Europe. This represents some kind of limited flexibility: sticking to harmonised allocation at an upper level, with market at assignment level. It could be said to fall into a category of "harmonised flexibility."

Hybridisation can also occur between comparative administrative procedures and auctions, as in regime 4a *Technology flexibility in Command and Control context* exemplified by the 2006 "Wimax" authorisation procedure in France. It combined qualitative elements submitted to administrative evaluation, like the contribution to regional development, with financial bids. It can also be presented as auctions with room for negotiations and mediation by the regulator. As the regulator retains the upper hand in the mix of criteria, we consider it to fall, as a variant, into the administrative procedures category, rather than the auctions category.

Regime 5b *Harmonised flexibility Plus* seems like an interesting combination of harmonised frequencies, technical flexibility, and easements on property rights acquired through auctions, thus accommodating some of operators' preferences, as well as possibilities of sharing and dynamic frequency selection.

Not all regimes are representative of realistic alternatives, but homage should be paid to regime 9 *California Dream,* which embodies the vision of a vast radio spectrum commons, supposing that the technologies exist to support it.

We have shown that flexibility and efficiency in spectrum management has to be considered at various levels and can be combined in a variety of ways. Let us now expose the iteration of pragmatic considerations at four successive levels of analysis leading to the choice of a spectrum regime.

2. Deciding on spectrum management regimes: The 4-step decision process

Efficiency is often quoted in relation to flexibility. We can refer to the ERO 80 Report definition of flexibility[11] as:

"*Increasing the ability of the spectrum regulatory framework to facilitate and adapt, in a timely manner, to user requirements and technological innovation by reducing constraints on the use of spectrum and barriers to access spectrum*."

We can see that flexibility is easily accommodated within the proposed analytical taxonomy, as it takes place at all four decision levels: frequency allocation, technology, usage rights, and assignment procedure. We now have the possibility to look at spectrum efficiency against this comprehensive and articulated framework to gain a better understanding of what is at stake in the present debate.

Let us look at the criteria decision-makers can resort to when going through the four steps constitutive of spectrum policy choices.

On the two issues of harmonisation and standardisation, it is to be noted the existing literature provides neither positive nor negative compelling evidence on their overall necessity and superiority to non-harmonisation and non-standardisation. Moreover, the existing literature does not provide either a locally applicable toolbox of criteria to make easily the proper choices. The evidence itself is not yet conclusive. For instance, in the very popular area of mobile communications services, the jury is still out on the outcome of the confrontation between the GSM-UMTS standardisation line of action in Europe and the agnostic approach adopted by the U.S. and Korea.

Industry associations, however, at least in Europe, have taken a contrarian view on service and technology flexibility in mobile services, and emphasised the benefits of harmonisation and standardisation in two recent studies (GSMA and UMTS Forum, 2006).

From this perspective, the critical questions to be answered when making choices of harmonisation versus non-harmonisation, and of standardisation versus non-standardisation, consist in the practical, future-oriented evaluation of two categories of factors. In short, the general trade-offs in matters of spectrum harmonisation and wireless technology standardisation are as follows.

[11] CEPT-ERO Report 80: *Enhancing harmonisation and increasing Flexibility in Spectrum Management,* www.ero.dk/, March 2006

2.1. Step 1: Harmonisation?

Harmonisation is meant to minimise interferences, reduce cross-border coordination requirements and ensure roaming facilities. The benefits for consumers result from the lower network planning expenses and lower prices of devices. The costs of harmonisation are the inefficiency costs incurred from local or overall suboptimal usage of the spectrum resource, administrative costs and slower innovation.

It then can be said:

Lemma 1: Harmonisation costs and benefits
If the cost differential induced at network gear and device levels by lack of harmonisation is low, economies of scale apply to the whole industry, even in a non-harmonised frequency bands regime. If the differential is high, harmonisation must prevail.

In other words, the question to be answered by decision-makers is:

- How much does the lack of, or only partial, harmonisation (like in the case of GSM bands in Europe and the US) impact the cost of network equipment, terminals and services?

2.2. Step 2: Standardisation?

It is generally accepted that there is a direct negative relation between production scale and the costs of manufactured products. Standardisation leading to an increase in scale is intended to lower the costs. The argument against (costs of-) standardisation (government or even industry-led) is that it creates a lock-in, which slows or even precludes the introduction of innovative, unexpected and un-expectable technologies. The risk is then that the industry is stuck with inferior technology. At the highest conceptual level, dynamic efficiency must prevail upon static considerations: innovation being by essence largely unpredictable, government-led standardisation would have to be avoided and industry-led standardisation to be carefully monitored to avoid the

establishment of barriers to entry. Eventually, the trade-off is between lower costs made possible by economies of scale on the plus side and potential barriers to entry for innovative new technologies on the minus side.

Lemma 2: Rate of technical progress and standardisation

If it can be safely assumed that technical progress for network equipments and terminals in a significant period under consideration (10-15 years) can be anticipated, or accommodated within designated standards or standard categories, the benefits of standardisation apply. If too much uncertainty regarding future technologies exists, or if a careful examination of developments in the labs leads us to assume there is a risk of major disruptive changes, avoiding standardisation is the safe bet. Game theory or probabilities can be of use in the decision-making process.

- The question about standardisation is: how much is lost in terms of extra costs for consumers if terminals have to combine two or more standards? Is our grasp of the technological paradigm in wireless for the next 10-15 years strong enough to aim at the benefits of standardisation, or is there a risk we might miss valuable opportunities, like those offered for instance by sharing, collective use and DFS, and in what timeframe?

2.3. Step 3: What type of usage rights?

Exclusive property rights

Property rights, in the area of spectrum, are favourably described as fostering efficient use, allowing more players to access the resource, and, when combined with trading, introduce an element of smooth and efficient flexibility in accordance with economic optimality criteria. Many advocate that they must be exclusive (without easements), to confer the licensees the benefit of a "clean spectrum", free of interferences.

The costs and potential risks include the creation of entry barriers in access to non-replicable resources, fragmentation, hoarding, pre-emption, market dominance, foreclosure of new entrants, in a context of vertical and horizontal integration, thus creating a potentially harmful situation with no remedies.

Looking at exclusive property rights assigned through market mechanisms, whatever the harmonisation and standardisation context, many question their ability to foster competition and efficiency in spectrum usage on the grounds

that strategic use and significant market power lurk around the corner. They dispute the view held by the FCC and OFCOM that, should Significant Market Power situations arise, they could be dealt with through standard generic competition monitoring rules and procedures. They argue exclusive property rights on limited resources intrinsically build up to barriers to entry and have a negative impact on flexibility.

An interpretation of the obligations formally or informally imposed on operators by regulators to subcontract part of their capacity to MVNOs is precisely that they have had to mitigate the exclusive character of the licenses by imposing or inducing some kind of sharing.

Property rights with easements

The introduction of easements would be justified by recent advances in low power and dynamic frequency selection (DFS), also called dynamic spectrum access networks (DySpaN), They have led some to think that spectrum efficiency would be increased by easements permitting sharing, overlay, underlay, without harmful interference.

Collective use

Collective use refers to access to license-exempt bands, an "etiquette" limiting, but not preventing interferences.

- The benefits of collective use include:

- Low entry barriers
- Quickly addressed niche applications
- Certainty of obtaining access
- Lower demand for licensed spectrum
- Innovation (anti-monopoly)
- Public infrastructure
- Freedom of speech/cultural diversity
- Light licensing
- Possibility of Private commons or Experimental commons

- The collective use costs are technical restrictions and higher risks of interference.

The EU study on collective use presents an up-to-date assessment of the potential extent of this category of usage rights.[12]

Deciding on spectrum usage rights

In deciding on the nature of spectrum usage rights, two levels of analysis have to be considered. The first is the relevance and institutional acceptability of the property-rights framework in the radio frequency spectrum area. It actually confronts decisions-makers with difficult social and political choices, very much related to the general institutional setting and mood in each country: the extension of property-rights meets less resistance in the UK and U.S. than in other countries. A second level of analysis rests at the technology level: it concerns the reality and feasibility of the technologies justifying easements in the property rights category, and of collective use. If we generically call those "flexible technologies", we can envisage two simple scenarios:

- Scenario 1: "flexible technologies" work
- Scenario 2: "flexible technologies" don't work.

We then have two strategies:

- Allow for the possible advent and significant extension of "flexible technologies", and then either derive the greatest possible benefits if they work - or be left with an awkward and inefficient regulation framework if they don't.
- Stick to what we know best: property rights, and then be right if "flexible technologies" don't work, or miss a significant opportunity if they do.

Those scenarios, strategies and outcomes are summarised in the simple table below:

[12] *Study on Legal, economic and technical aspects of collective use of spectrum in the European Community* by Mott MacDonald Ltd, Aegis Systems Limited, IDATE, Indepen Ltd and Wik Consult

Strategies & scenarios for the decade ahead	**Scenario 1** **Advent of flexible use technologies**	**Scenario 2** **No significant difference In trend with present technology mix**
Exclusive Property Rights Strategy	**Consumer Welfare LOW**	**Consumer Welfare MEDIUM**
Policy-Mix (Easements & Collective Use) Strategy	**Consumer Welfare HIGH**	**Consumer Welfare LOW**

The assumptions made here are that:

- Sticking to exclusive property rights if flexible technologies are feasible leads to an inferior outcome in terms of consumer welfare.
- Flexible technologies are better accommodated by a regime-mix strategy that would include easements and collective use.

Decision theory illustrates how choices to be made under those conditions depend on the applied methodologies and the values of variables.

- If scenarios can be assigned probabilities, the outcome will depend on them. No objective probability being available, the exercise consisting in subjectively assigning probabilities to the scenarios, based on our "best knowledge" can significantly enlighten the decision process. Basically, if the "Advent of flexible technologies scenario" is considered the most probable, the "Policy-Mix" strategy wins. On the contrary, if this advent is considered

improbable, “Exclusive Property Rights Strategy” wins, unless the relative value of the “High consumer welfare” is very high.

- Alternatively, a very basic game-theoretic approach provides the following outcomes:

Posture	Criterion	Preferred Strategy
Aiming at the best (HIGH), but most risky, outcome	Maximax: maximum of maximum outcomes	Regime-Mix choice
Avoiding the worst outcome (LOW):	Minimax: minimum of maximum outcomes)	Exclusive property rights Choice
Intermediate	Minimax regret: minimum of maximum regret (regret being intended as the difference between the actual outcome of a strategy and the outcome obtained if the best strategy had been chosen in each scenario)	Depending on quantitative values of High, Low, and Medium.

2.4. Step 4: What kind of spectrum assignment mode should be adopted?

Administrative assignment procedures/hybrid procedures

Regulators have made significant efforts over the last decade to keep up with market changes and innovations. Some contend, however, that administrative methods might have reached a limit and that the situation and inconsistencies in spectrum management regimes actually hinder the deployment of new technologies. Advocates of administered flexibility, intended as flexibility achieved within an administered setting, argue that the complexity of spectrum usage, namely the prevention of interferences, demands strong control mechanisms. They add that even if it represents some costs, those are smaller than those induced by the multiplication of conflicts and litigations that would occur in their absence. There should be a trade-off between the costs induced by sub-optimal administrative procedures and the technical monitoring, adjustment costs and litigation costs they help avoid.

Hybrid procedures (administrative with bidding as a criterion among others) have the positive effect of combining:

- Welfare considerations
- Domestic and international security concerns
- Preserving national or regional champions to a certain degree
- Capturing rents (possibly by maintaining them?).

Some governments, not all, are willing to implement this set of criteria and design their procedures accordingly. Others favour a more radical market approach across the board.

Auctions/trading

Whether market mechanisms in the form of auctions and trading can bring competition and efficiency in spectrum usage is hotly debated. Some agencies are optimistic that competition will take place. The pro-market line of reasoning taken by the FCC Task Force 2002 report and the Radio Agency Martin Cave 2002 reports refer to the respectable consideration that the introduction of market mechanisms optimises the usage of spectrum, as of any other resource. It would basically seem that the same holds for the policy orientations upheld by the European Commission: what they propose, not without merit, is an extension to spectrum of the general internal market principles, which are the backbone of the EU economic propositions. As for trading, it is usually thought of as a way either to correct initial flaws in allocation or assignment, or to allow for changes over time.

On the minus side, the existence of a budgetary bias is a case in point: in situations of doubt as to the most efficient spectrum management regime, budgetary considerations will have assignment methods providing the maximum income for the government budget prevail. Governments have often clashed with regulators as the consideration of cash-strapped budgets has overwhelmed any other, including consumer welfare.

3. Navigating the nine spectrum management regimes: migrations and transitions

It is too early to provide a fact-based assessment of each of the nine spectrum regimes presented. It is also true that most agencies in charge of spectrum, even those advocating a strong market-orientation like OFCOM or the FCC, tend to adopt a careful and progressive approach to changes in management methods; the road to a competitive spectrum market is more evolutionary than revolutionary. The specifications and restrictions attached to the frequency usage plan are progressively softened or lifted, and possibly changed into an orientation framework. In this sense, the variety of spectrum regimes presented in this paper can provide a map on which an evolutionary path from one spectrum regime to another may be traced, alongside evolutions in wireless technologies and spectrum usage. The actual implementation of cognitive radio, dynamic frequency selection, for instance, could warrant an extension of easements over time.

Given the strong interaction of decisions on frequency bands, service applications, and technology assessments, which constitutes the basic foundation of the choice of a spectrum management regime, it is advisable to operate those choices for relevant sets of bands, services, and technology areas, which we call wireless clusters. Such clusters would include, for instance, mobile voice and television, fixed wireless access, professional mobile radio, collective use, public safety, etc.[13] From this perspective, there might be migrations over time from one spectrum regime to another, to implement changes required by demonstrated positive technological changes. Instead of a war of doctrines between command and control, market and commons, we could have, when required for a cluster of wireless services, an evolutionary process over time between progressive spectrum regimes.

It should be remembered throughout this evolutionary process, however, that like at a higher level of policy consideration, efficiency lies in tough choices. If we look at the strongest performing economies over the last 50 years, good performances have been achieved by market economies like the U.S. and UK on the one hand, as well as co-ordinated social market economies like Germany, Japan, Ireland and the Netherlands on the other. Countries in the middle have performed less strongly. This may indicate that the problem lies not with market mechanisms, or more social models per se, but with distortions resulting from their application being only partial: a significant part of our present spectrum situation is due to the fact that part of the commercial spectrum is managed in an

[13] SPORT VIEWS *Study Report* March 2007, www.sportviews.org

un-commercial way. If the broadcasting industry had been offered the possibility to trade (sell) its spectrum, maybe it would have found more profitable to do so and use the proceeds to expand its cable, satellite, and ADSL TV operation, instead of switching from analogue to digital on terrestrial.

Legacy and institutional factors might play a bigger role than markets and technologies, especially as the time horizon and gradient are superior to that usually encountered in business and industry. How can you have trading, or auctions for that matter, if this is an anathema to powerful and vocal players? What could then be a second-best approach if market-induced flexibility cannot be extended right across the EU? One first element of an answer is easements, sharing, collective use, and dynamic access. Some sharing will have to take place due to the expected limitations of spectrum available for IMT and beyond. Furthermore, new technologies will help bridge the gap between static (short-term) and dynamic (long-term) efficiency as embedded in the standardisation versus non-standardisation dilemma. They substitute families of contiguous technologies to single technologies at any single time. They also facilitate smooth evolutionary transitions over time, enabling dynamic efficiency, and lifting the curse of necessary disruptions between discrete standards. The same evolutionary vision could apply to spectrum management regimes.